TESTIMONY OF
J. MICHAEL SILVA, P.E.

PRESIDENT
ENERTECH CONSULTANTS

Subject: Engineering Evaluation of Electric and Magnetic Fields

INTRODUCTION

Q. Please state your name and business address.

A. My name is J. Michael Silva and my business address is 300 Orchard City Drive, Suite 132, Campbell, California.

Q. What is your occupation?

A. I am a research engineer, specializing in assessing exposure to extremely low frequency electric and magnetic fields (called EMF).

Q. What is your position at ENERTECH Consultants?

A. I am President of the company.

Q. What is ENERTECH Consultants?

A. ENERTECH Consultants is a 22-year old consulting and scientific research firm that specializes in applied research projects, engineering, exposure assessment, and the development of EMF measurement instrumentation and computer modeling software. We have approximately 20 employees in two offices and are involved in a variety of research and consulting projects.

Q. Please describe your educational background.

A. I have a Bachelor of Science degree in Engineering from the University of Alabama and a Master of Science in Engineering from Auburn University.

Q. Are you a registered professional engineer?

A. Yes, I have a professional engineering license in Electrical Engineering in California, and I am also a registered professional engineer in the states of Alabama, Connecticut, Massachusetts, Pennsylvania, Nebraska, and Texas.

Q. Are you a member of any professional organizations?

A. Yes, I am a Senior Member of the Institute of Electrical and Electronics Engineers ("IEEE"). Within that organization, I served for about ten years as the Secretary of the Power Engineering Society's Corona & Field Effects Subcommittee. I am also a member of the IEEE Design and Environmental Considerations Working Group and the AC Fields Working Group. I am also a member of the Bioelectromagnetics Society ("BEMS") and the Institute of Navigation ("ION"). I have also served as a scientific publication reviewer (referee) for papers submitted to scientific journals for publication, including <u>IEEE</u>, <u>BEMS</u>, <u>Journal of Exposure Analysis and Environmental Epidemiology</u> and the <u>American Journal of Epidemiology</u>.

Q. Have you received any special recognition for your work involving EMF exposure assessment?

A. Yes. At the University of Southern California, I was the Lloyd Hunt Distinguished Lecturer in Power Engineering. I have also been a guest lecturer at the Ohio State University Electrical Engineering colloquium - Distinguished Lecture Series, and I was invited as a guest lecturer at the University of Texas at Austin Power System Seminar Lecture Series and also at the Power Distribution Conference. I was selected in 1978 to represent the United States in technical meetings with the former Soviet Union, I was a member of the IEEE team that wrote the US National Standard for how to measure EMF. I have also received recognition awards for my work on IEEE and international technical papers and my work on technical committees.

Q. Please briefly describe you work experience.

A. I worked at the Southern Company from 1971 until 1977 in electric transmission line design. As supervising engineer, I was responsible for the detailed design of high voltage electric transmission lines from 46 kV to 500 kV on the Southern Company's electric transmission system in Alabama, Florida, and Mississippi.

These responsibilities included development of the engineering details and design specifications necessary for construction of these lines. I was also responsible for conducting studies of the electrical environment in the vicinity of high voltage electric transmission lines and substations, including EMF calculations and measurements. In 1977, I was appointed Project Manager of the Alternating Current and Direct Current Research Program for the Electric Power Research Institute ("EPRI") in Palo Alto, California. I was responsible for AC and DC electric transmission line research at several facilities located across North America. These research projects included design considerations for electric lines, evaluations of electric and magnetic fields, field induction, spark discharge and corona studies, instrumentation for field measurements, and many other technical areas. From 1979 to early 1982, I worked at a consulting engineering firm in Pittsburgh, Pennsylvania. My duties included managing and conducting several transmission line projects and various transmission line design and engineering jobs nationwide. In early 1982, I founded Enertech Consultants, a scientific research and consulting firm with offices in California and in Massachusetts. Enertech performs scientific research, develops EMF modeling software, and design, manufacturers and sells EMF measurement instrumentation in 42 countries.

Q. For how many years have you been involved in performing EMF studies and assessments?

A. The majority of my work over the past 32 years was related to electric power facilities or EMF studies and assessments at locations throughout the United States and in other countries.

Q. Could you briefly describe the types of projects that you have been involved in as a research engineer with an emphasis in EMF studies?

A. We perform work related to electric and magnetic fields in three broad areas. First, we conduct applied research projects involving EMF exposure assessment. In this area we have worked on several major projects, including studies conducted by researchers for Johns Hopkins University, the University of North Carolina, the Electric Power Research Institute (EPRI), the California Department of Health Services, the U.S. Department of Energy, and the National Cancer Institute. Second, we develop instrumentation for accurate measurement of EMF and conduct a variety of measurement programs throughout the world. Third, we develop computer software for calculating EMF levels, analyzing measurement data and modeling EMF environments and exposure.

Q. What do you mean by the term "exposure assessment"?

A. By "exposure assessment" I mean the evaluation of people's exposure to EMF through measurement, modeling, calculations, or other techniques.

Q. Could you please provide more detail on some of your more current applied research projects?

A. I worked as a member of a research team on a large study of electric utility workers. Our role has been to characterize the magnetic field exposure encountered by these electric utility workers. In a recent Nationwide Residential Study, I was responsible for the measurement of magnetic fields in about 1,000 homes in 25 utility service areas. For the California Department of Health Services we completed another large project involving a comprehensive 3-year survey of EMF in California Schools and a study of teachers' exposure and sources. As part of a large childhood epidemiological study conducted by the National Cancer Institute, our research team was involved in the effort to measure magnetic fields in homes in eleven states and included wire coding on over 1,300 homes. And, we completed a study for the EMF RAPID Program of the National Institute of Environmental Health sciences involving personal exposure measurements for over 1,000 randomly selected Americans located throughout all 50 states. And we recently completed a three-year EMF measurement program for the United Nations at their headquarters buildings in New York City.

Q. Would you please identify some of the organizations whom ENERTECH has performed EMF measurements and exposure assessments or EMF consulting work for in the past?

A. Yes. We have conducted such work for a number of clients in the United States, Europe, Australia, and Canada including the California Department of Health Services, the Electric Power Research Institute, CISCO Systems, the U.S. Department of Justice, a variety of electric utilities, Stanford University, the Montecito and Selma Unified School Districts in California, the Jefferson County School District in Colorado, Mesa School District in Arizona, City of Austin, Texas, Kaiser Permanente Hospitals, Bay Area Rapid Transit (BART), Davies Medical Center, University of California at San Francisco Medical Center, the Metropolitan Water District in Los Angeles, Microsoft, Walt Disney Company, Washington University, Roadway Powered Electric Vehicle Project, U.S. Department of Energy, San Diego Transit Authority, U.S. Air Force, United Nations, the state of Wisconsin Public Service Commission, the state of Nevada Public Utility Commission, and many other clients.

Q. Can you please provide a copy of your resume?

A. Yes. My resume has been marked as Exhibit HECO-1000.

SCOPE OF TESTIMONY

Q. What is the scope of your testimony?

A. I was asked to provide testimony on the East Oahu Transmission Project to address four areas: first, to generally describe EMF and the units of its measure; second, characterize EMF levels from the underground transmission line design 138 kV and 46 kV alternatives proposed for this project; third, my assessment of underground line design features that reduce EMF levels, and fourth, provide examples of typical EMF sources and the range of levels commonly encountered in everyday life.

Q. What did you do to develop your testimony?

A. I reviewed a number of documents related to this proceeding, including Appendices J and L in Volume 3 of the September 1999 "Kamoku-Pukele 138kV Transmission Line Project Revised Environmental Impact Statement" ("REIS Volume 3") and Section 4.21 in Volume 1A of the September 2000 "Kamoku-Pukele 138kV Transmission Line Project Revised Final Environmental Impact Statement" ("RFEIS Volume 1A") where both documents are included in this Application as part of HECO Exhibit-4. In addition, I reviewed the September 29, 2003 Technical Report by Enertech, "Magnetic Field Measurement and Modeling Assessment for Proposed HECO 46 kV Underground Cables" ("Enertech 2003 Technical Report") included in this Application as HECO Exhibit-8.

EMF DESCRIPTION

Q. Is there a difference between magnetic fields and the term EMF?

A. EMF is a term used for Electric and Magnetic Fields, but often, EMF is used only to refer to the magnetic field. Since the underground cables proposed for this project do not produce electric fields above ground due to cable and earth shielding, I use the term EMF in my testimony to mean just the magnetic field.

Q. What are magnetic fields?

A. A field is a space or region in which an influence exists. For example, a temperature field exists in the space around a hot or cold object. A magnetic field is produced by electrical devices due to the flow of an electric current. One of the characteristics of a magnetic field is that it decreases with distance away from the source.

The most common unit used by engineers for describing magnetic fields is the Gauss (G). It is a unit of magnetic intensity over an area. Since the gauss is too large to describe most everyday magnetic fields, often a much smaller unit, the milligauss (mG), is used to describe the magnetic field. One milligauss equals one thousandth of a Gauss (1 mG = 0.001 G).

The earth itself has a static, or direct current, DC magnetic field. In Hawaii, the earth's magnetic field is about 360 milligauss (mG). It should be noted that the earth's fields are primarily static fields rather than alternating fields, and therefore they do not necessarily compare directly with 60 Hertz AC fields because static fields do not change direction over time as AC fields do.

Q. What does "60 Hertz" mean?

A. Hertz (Hz) is the unit of measurement for frequency. Frequency is the number of complete alternations or cycles of a wave during a period of time, sometimes called "cycles per second." The term 60 Hz means 60 cycles per second. For alternating current (AC) electric power lines, the voltage and electric current reverse direction (polarity), at a rate of 60 complete alternations or cycles per second. If there are no alternations, it is direct current (DC), or static. A static field thus has a frequency of zero Hz.

Q. Why is frequency important in understanding EMF?

A. EMF has two important characteristics: frequency and intensity (magnitude). For power lines and most appliances, the direction of electric current flow, as described above, alternates at a frequency of 60 times (cycles) per second and the fields associated with these sources are said to be 60 Hz fields. Cellular telephones, for example, are small radio transmitters and receivers that operate at either about 850 million Hertz or 1.9 billion Hertz. The frequency of a field affects the amount of energy the field can deliver. This explains why the field in a microwave oven (frequency of 2.45 billion Hertz) can directly cook food and the field associated with a can opener (frequency of 60 Hertz) will not. Frequency is an important factor to consider when comparing different devices. For example, this is why the EMF of a 60 Hz electric power line cannot be compared with the EMF of a cell phone.

Q. What factors influence the intensity of EMF from a source?

A. In general, magnetic fields are a function of the load current (measured in amperes), the physical configuration, phasing and, importantly, the distance away from the source. The intensity of EMF drops of with distance, sometimes very quickly. Devices like a hair dryer or even an electric power transformer are called "point sources" and the field drops off rapidly, generally as a function of the inverse of the distance cubed. For example, if the field at 1 ft from a hair dryer were a certain level, the field at 2 ft would only be 1/8th of the initial level, significantly less. Devices like power lines and cables are called "linear sources" and the field also drops off rapidly from them, generally as a function of the inverse of the distance squared.

Q. What are some common sources of EMF?

A. EMF is created whenever electricity is present. Household wiring, electric transmission and distribution facilities, lighting, appliances, transportation, amusement park rides, video arcades, office or industrial equipment, and even some toys are all examples of common sources of EMF.

Q. How do everyday activities expose us to EMF?

A. Exposure to EMF results from a variety of situations and sources routinely encountered in everyday life. An individual's exposure to EMF will be composed of the many common exposures at home, work, businesses, school, recreation, and other locations. Exposures to appliances and other electric devices can range from brief to more lengthy periods of time. For example, a clock radio, air conditioner, fan or even water pipes (with ground currents) located near a bed or living room chair can bring people near everyday field sources for long periods of time. A number of typical employment and other locations, for example, near a cash register, service counter, display case, or video games, could result in a range of field exposures. In summary, there is a range of magnetic field exposures and variety of sources encountered in everyday activities

Q. What are EMF levels near some common appliances?

A. The measured EMF level at 12-inches from typical appliances are in the 1-250 mG range, with maximum values up close to the appliance of 3-20,000 mG (Table 2, Appendix J, REIS Volume 3).

TYPICAL EMF MEASURED IN HONOLULU

Q. Did you evaluate EMF levels found in typical locations in Honolulu?

A. Yes. I reported on a variety of EMF measurements made in Honolulu in the REIS Volume 3 (Appendix J) and tabulated the measurements in the RFEIS Volume 1A (Section 4.21).

Q. Can you please summarize the EMF levels found at typical locations in Honolulu?

A. Yes. A variety of EMF measurements were made at 55 Honolulu locations in the Makiki, Kaimuki, and Palolo districts. At outdoor locations like bus stops and sidewalks the EMF levels had a range of 0.2 – 41.8 mG, with an average value of 5.2 mG (Table 4-27, RFEIS Volume 1A). Measurements at 16 indoor locations like restaurants, schools, markets, and shops were in the range of 0- 1,649 mG, with averages of 0-27 mG (Table 4-28, RFEIS Volume 1A). Personal exposure measurements for 7 volunteers ranged from 0- 430 mG, with 24-hour averages of 0.7-3.2 mG (Table 4-30, RFEIS Volume 1A). Measurements around 3 electric power substation perimeters ranged from 0.3- 52.1 mG (Table 4-25, RFEIS Volume 1A). Measurements at 5 locations above 46 kV underground cables ranged from 6.9- 49 mG (Section 3.3, Enertech 2003 Technical Report).

CALCULATED PROJECT EMF LEVELS

Q. What underground transmission line cable alternatives are proposed in this application for the East Oahu Transmission Project?

A. The Project has proposed two different high voltage classifications for the underground cables: 138 kV cables and 46 kV cables.

Q. Please generally describe the 138 kV cable design proposed for the Project?

A. There are two technologies that could be utilized for the 138 kV underground transmission line: High-Pressure Fluid Filled (HPFF) cables or Cross-Linked Polyethylene (XLPE) cables. In the HPFF design (commonly called "pipe-type" cable), the energized conductors are surrounded by a special insulating fluid and enclosed in a low-carbon steel pipe. In the XLPE design (commonly called "solid dielectric" cable), the energized conductors are surrounded by extruded polyethylene insulation and enclosed in a protective metallic sheath and polyethylene jacket.

Q. Is there a difference in EMF levels produced by the two different cable designs?

A. Yes. The High-Pressure Fluid Filled (HPFF) cables would have significantly lower EMF levels than the Cross-Linked Polyethylene (XLPE) cables. This is because the low-carbon steel pipe of the HPFF system surrounds the cables and provides an effective attenuation (shielding) of the magnetic field external to the steel pipe. The XLPE system is does not require a steel pipe and consequently would have higher EMF levels than the HPFF design.

Q. Please generally describe the 46 kV cable design proposed for the Project?

A. The 46 kV underground transmission lines would utilize Cross-Linked Polyethylene (XLPE) cables (three cables per electrical circuit) placed within underground PVC ducts and encased in concrete. Depending on the project segment, some locations would utilize either single, double, or triple circuit 46 kV cables to achieve the necessary load transfer capability.

Q. Have the EMF levels been calculated for the proposed 138 kV and 46 kV underground cable alternatives?

A. Yes. The REIS Volume 3 (Appendix L) provides the calculated 138 kV EMF levels and the Enertech 2003 Technical Report provides the 46 kV EMF levels.

Q. What cable loading conditions were used for the EMF calculations?

A. The EMF levels have been calculated for two loading cases- Normal and Emergency loading for both the 138 kV and 46 kV underground cable designs.

These are the cable loadings that are the "maximum cable ratings" for typical operation under normal and emergency conditions. The HECO cable loadings are based on recommended values provided by engineering standards for the maximum allowable conductor temperatures for normal operation and for emergency operation of cables. The HECO assessment of the circuits involved for the project indicate that the actual loads on the underground cables would be less than these "maximum cable ratings" for both normal and emergency conditions. Therefore, the EMF calculations are conservative and would generally overstate EMF levels such that the project would have lower levels than was calculated.

Q. In general, how do EMF levels fall off or attenuate with distance away from the underground electric power cables?

A. EMF levels drop very quickly with distance away from underground cables due to the close spacing between the electrical conductors. The attenuation rate is more rapid for underground in comparison with overhead lines that have a larger conductor spacing. In addition, where any transmission line has adjacent multiple circuits, the phasing of nearby conductors can be arranged so as to cause a partial cancellation of EMF and result in an overall reduction of EMF levels.

Q. Please describe the EMF levels for Normal and Emergency loading for the proposed 138 kV underground alternatives?

A. The EMF levels can be characterized for the Normal and Emergency loading cases by the calculated maximum level above the underground cable and at a distance of 50 ft away (Sections 5.1 and 5.2, REIS Volume 3, Appendix L). The EMF levels drop rapidly with distance away from the cables. For the 138 kV HPFF cable, the maximum EMF level above the cable ranges from 2.6 mG (Normal) to 3.3 mG (Emergency); at 50 ft away, the EMF level is about 0.06 mG for both load cases. For the 138 kV XLPE cable, the maximum EMF level above the cable ranges from 31.3 mG (Normal) to 76 mG (Emergency); at 50 ft away, the EMF level ranges from 1.7 mG (Normal) to 4.5 mG (Emergency).

Q. Please describe the EMF levels for Normal and Emergency loading for the proposed 46 kV underground alternatives?

A. The EMF levels can be characterized for the Normal and Emergency loading cases by the calculated maximum level above the underground cable and at a distance of 50 ft away (Section 5.3, Table 2, Enertech 2003 Technical Report). The EMF levels drop rapidly with distance away from the cables. The 46 kV alternatives propose a variety of 46 kV underground construction consisting of either single, double, or triple circuit 46 kV cables, depending on the load transfer requirements at each location. For the single circuit 46 kV cable sections, the maximum EMF level above the cable ranges from 79.7 mG (Normal) to 95.2 mG (Emergency); at 50 ft away, the EMF level ranges from 1.6 mG (Normal) to 1.9 mG (Emergency). For the double circuit 46 kV cable sections, the maximum EMF level above the cable ranges from 134 mG (Normal) to 162.6 mG (Emergency); at 50 ft away, the EMF level ranges from 2.7 mG (Normal) to 3.3 mG (Emergency). For the triple circuit 46 kV cable sections, the maximum EMF level above the cable ranges from 143.3 mG (Normal) to 176.6 mG (Emergency); at 50 ft away, the EMF level ranges from 3.2 mG (Normal) to 4 mG (Emergency).

EMF MITIGATION

Q. Were you asked to evaluate EMF mitigation options for the proposed 46 kV alternative?

A. Yes, I performed an evaluation of mitigation options for the proposed 46 kV alternative.

Q. Please describe how EMF can be mitigated for the proposed underground circuits?

A. EMF mitigation, or reduction in EMF levels, can be achieved for multiple circuit power lines with similar loads by optimizing the cable placement and phasing arrangement within the cable ducts. Optimized placement of multiple circuit cables can achieve a partial cancellation of EMF and result in reduced EMF levels when circuits are similarly loaded. The maximum EMF cancellation occurs when all circuits have identical loads and their individual phases are placed in an optimum manner in adjacent ducts. In general, multiple circuits will not always have simultaneous identical loads, so that EMF reduction is less when circuit loads are not the same.

Q. Please describe the cable placement and phasing arrangement for the multiple circuit 46 kV underground lines for optimum reduction of EMF levels?

A. A variety of cable placements and phasing arrangements were studied for the 46 kV circuit cable sections to determine the optimum phase configuration for EMF reduction. The optimum configurations are described in Section 5.4 of the Enertech 2003 Technical Report. For the 46 kV double circuit configuration, the optimized configuration is to arrange each circuit horizontally within the duct, with one circuit directly above the other circuit, and with unlike or opposite phasing (see Enertech 2003 Technical Report, Section 5.4, Fig. 18). For the 46 kV triple circuit configuration, the optimized configuration is to arrange each circuit vertically within the duct, with one circuit directly adjacent to the other circuit, and with a specific phasing arrangement (see Enertech 2003 Technical Report, Section 5.4, Fig. 20). When the circuits do not have identical loading, the cancellation effect is less; therefore, the calculations for identical circuit loading provide an upper bound for EMF reduction. The optimum phasing option is not available for the single circuit 46 kV or 138 kV cables because there is no adjacent circuit to create the partial EMF cancellation.

Q. What were the results of your EMF calculations for optimum circuit and phasing arrangement for the proposed 46 kV alternative?

A. The calculated results for multiple circuit 46 kV cables shows that use of optimum phase placement in the cable ducts can reduce EMF levels by a maximum amount of about 87% when all circuits have identical loads (Section 5.4, Table 3, Enertech 2003 Technical Report). The EMF levels can be characterized for the Normal and Emergency loading cases by the calculated maximum level above the underground cable and at a distance of 50 ft away for circuits with assumed identical loads. For the <u>double circuit</u> 46 kV cable sections with optimized phasing and identical circuit loads, the maximum EMF level above the cable ranges from 16.2 mG (Normal) to 19.6 mG (Emergency); at 50 ft away, the EMF level is about 0.1 mG for both load cases. For the <u>triple circuit</u> 46 kV cable sections with optimized phasing and identical circuit loads, the maximum EMF level above the cable ranges from 19.3 mG (Normal) to 23.8 mG (Emergency); at 50 ft away, the EMF level is about 0.1 mG for both load cases.

<u>EMF STANDARDS</u>

Q. Does the United States Government have EMF standards?

A. No.

Q. Does the State of Hawaii have EMF standards?

A. No.

Q. Do any organizations have occupational EMF standards or guidelines?

A. Yes. The International Commission on Non-Ionizing Radiation Protection (or, ICNIRP) and the American Conference of Governmental Industrial Hygienists (or, ACGIH) both have EMF exposure guidelines.

Q. Who is The International Commission on Non-Ionizing Radiation Protection?

A. The International Commission on Non-Ionizing Radiation Protection is an organization of 15,000 scientists from 40 nations who specialize in radiation protection.

Q. Who is The American Conference of Governmental Industrial Hygienists?

A. The American Conference of Governmental Industrial Hygienists (ACGIH) is a professional organization with an emphasis on occupational factors.

Q. What are the occupational EMF standards or guidelines?

A. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has an occupational exposure limit of 4,167 mG (for the general public the continuous exposure level is 833 mG), and the American Conference of Governmental Industrial Hygienists (ACGIH) has a limit of 10,000 mG.

Q. Would the proposed East Oahu Transmission Project comply with these EMF guidelines?

A. Yes. The East Oahu Transmission Project would have EMF levels far below the EMF standards of ICNIRP and ACGIH.

CONCLUSIONS

Q. Please summarize the conclusions reached in your testimony.

A. There is nothing unusual about the underground lines proposed for the East Oahu Transmission Project. The underground cables and the associated EMF levels are similar to other underground cables presently operating throughout Hawaii and on the mainland. The EMF levels from the underground cables drop significantly with distance away from the cable. The EMF levels are similar to everyday EMF levels typically encountered in Honolulu. The EMF levels from the Project are far below EMF standards. EMF can be significantly reduced (by up to 87% for identically loaded circuits) for the double and triple circuit 46 kV cable sections by use of optimized cable placement and phase arrangements.

Q. Does this conclude your testimony?

A. Yes, it does.